

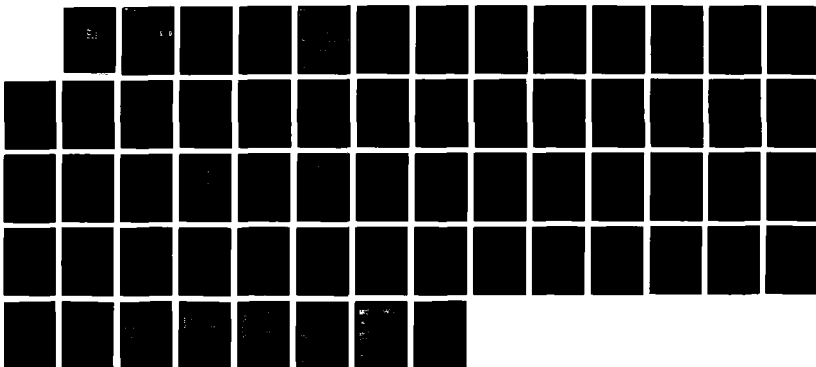
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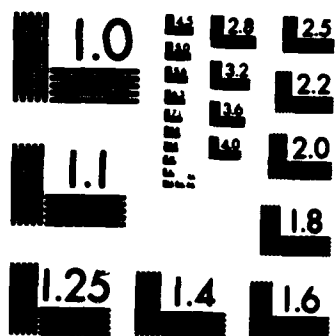
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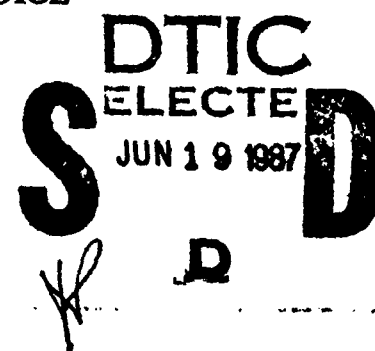
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CONTINGENT WEIGHTING IN JUDGMENT AND CHOICE

Amos Tversky
Stanford University, Stanford, California

Shmuel Sattath
Hebrew University, Jerusalem, Israel

Paul Slovic
Decision Research, Eugene, Oregon



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800 North Quincy Street
Arlington, VA 22217

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) > Preference can be inferred from direct choice between options or from a matching procedure in which the decision maker adjusts one option to match another. Studies of preferences between two-dimensional options (e.g., public policies, job applicants, benefit plans) show that the more prominent dimension looms larger in choice than in matching. Thus, choice is more lexicographic than matching. This finding is viewed as an instance of a general principle of compatibility: the weighting of inputs is enhanced by their compatibility with the output. To account for such effects, we develop a hierarchy of models in which the tradeoff between attributes is contingent on the nature of the response. The simplest theory of this type, called the contingent weighting model, is applied to the analysis of various compatibility effects, including the choice-matching discrepancy and the preference-reversal phenomenon. These results raise both conceptual and practical questions concerning the nature, the meaning and the assessment of preference.					
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The relation of preference between acts or options is the key element of decision theory that provides the basis for the measurement of utility or value. In axiomatic treatments of decision theory, the concept of preference appears as an abstract relation that is given an empirical interpretation through specific methods of elicitation, such as choice and matching. In choice the decision maker selects an option from an offered set of two or more alternatives. In matching the decision maker is required to set the value of some variable in order to achieve an equivalence between options (e.g., what chance to win \$750 is as attractive as 1 chance in 10 to win \$2500?).

The standard analysis of choice assumes procedure invariance: normatively equivalent procedures for assessing preferences should give rise to the same preference order. Indeed, theories of measurement generally demand that the ordering of objects is independent of the particular method of assessment. In classical physical measurement it is commonly assumed that each object possesses a well-defined quantity of the attribute in question (e.g., length, mass) and that different measurement procedures elicit the same ordering of objects with respect to this attribute. Analogously, the classical theory of preference assumes that each individual has a well-defined preference order (or a utility function) and that different methods of elicitation produce the same ordering of options. In order to determine the heavier of two objects, for example, we can place them on the two sides of a pan balance and observe which side goes down. Alternatively, we can place each object separately on a sliding scale and observe the position at which the sliding scale is balanced. Similarly, to determine the preference order between options we can use either choice or matching. Note that the pan balance is analogous to binary choice, whereas the sliding scale resembles matching.

In contrast to the rational theory of choice that assumes procedure invariance, psychological analyses suggest that choice is contingent, or context sensitive (see, e.g., Payne, 1982; Slovic, Lichtenstein & Fischhoff, in press; Tversky & Sattath, 1979). It appears that different methods of elicitation can give rise to different heuristic procedures, which produce different responses. To illustrate this process and motivate the present development, suppose Joan faces a choice between two job offers that vary in interest and salary. Being uncertain about the weighing of these attributes, she may adopt the following heuristic procedure. First, she examines whether one option dominates the other (i.e., is one option better than the other in all respects?). If not, she may try to reframe the problem to produce a dominant option. If no dominance emerges, she examines next whether one option enjoys a decisive advantage. That is, does the advantage of one alternative far outweigh the advantage of the other? If neither option has a decisive advantage, Joan may decide to select the option that is superior on the more important attribute. This procedure which is essentially lexicographic, has several attractive features: (i) it does not require the decision maker to assess the tradeoffs between the attributes, thereby reducing mental effort and cognitive strain, (ii) it is easy to describe and justify to oneself as well as to others, and (iii) it can be used to approximate more complex compensatory decision rules.

Suppose now that Joan has to determine the salary at which the less interesting job would be as attractive as the more interesting one. The heuristic procedure described above cannot be used to solve this problem, and Joan now must "bite the bullet" and assess her tradeoff between interest and salary, using some other heuristic. As a result, preferences induced by choice are likely to be closer to the lexicographic ordering than those induced by

matching, or equivalently, the more prominent attribute looms larger in choice than in matching. This is the *prominence hypothesis*.

The discrepancy between choice and matching was first observed in a study by Slovic (1975) that was motivated by the ancient philosophical puzzle of how to choose between equally attractive alternatives. In this study the respondents first matched different pairs of (two-dimensional) options and, in a later session, chose between the matched options. Slovic found that the subjects did not choose randomly but rather tended to select the option that was superior on the more important dimension. This observation supports the prominence hypothesis, but the evidence is not conclusive for two reasons. First, the participants always matched the options prior to the choice hence the data could be explained by the hypothesis that the more important dimension looms larger in the later trial. Second, and more important, each participant chose between matched options hence the results could reflect a common tie-breaking procedure rather than a genuine reversal of preferences. After all, rationality does not entail a random breaking of ties. A rational person may be indifferent between a cash amount and a gamble, and always pick the cash when forced to take one of the two.

To overcome these difficulties we develop in the next section a method for testing the prominence hypothesis that is based entirely on interpersonal (between-subjects) comparisons, and we apply this method to a variety of choice problems. In the following two sections we present a conceptual and mathematical analysis of contingent weighting, and apply it to several phenomena of judgment and choice. The theoretical and practical implications of the work are discussed in the final section.

TESTS OF THE PROMINENCE HYPOTHESIS

Interpersonal Tests

We illustrate the experimental procedure and the logic of the test of the prominence hypothesis in a problem involving a choice between job candidates. The participants in the first set of studies were young men and women (ages 20-30) who were taking a series of aptitude tests at a vocational testing institute in Tel Aviv, Israel. The problems were presented in writing, and the participants were run in small groups. They all agreed to take part in the study, knowing it had no bearing on their test scores. Some of the results were replicated with Stanford undergraduates.

Problem 1 (Production Engineer)

Imagine that, as an executive of a company, you have to select between two candidates for a position of a Production Engineer. The candidates were interviewed by a committee who scored them on two attributes (technical knowledge and human relations) on a scale from 100 (superb) to 40 (very weak). Both attributes are important for the position in question, but technical knowledge is *more important* than human relations. On the basis of the following scores, which of the two candidates would you choose?

	Technical Knowledge	Human Relations	[N=63]
Candidate X	86	76	[65%]
Candidate Y	78	91	[35%]

The number of respondents (N) and the percentage who chose each option are given in brackets on the right-hand side of the table. In this problem, about two-thirds of the respondents selected the candidate who has a higher score on the more important attribute (technical knowledge).

Another group of respondents received the same background material except that one of the four scores was missing. They were asked "to complete the missing score so that the two candidates would be equally suitable for the job". Suppose, for example, that the lower left-hand value (78) were missing from the table. The respondent's task then is to generate a score for Candidate Y in technical knowledge so as to match the two candidates. The participants were reminded that "Y has a higher score than X in human relations, hence, to match the two candidates Y must have a lower score than X in technical knowledge".

Assuming that higher scores are preferable to lower ones, it is possible to infer the response to the choice task from the response to the matching task. Suppose, for example, that one produces a value of 80 in the matching task (when the missing value is 78). This means that X's score profile (86,76) is judged equivalent to the profile (80,91), which in turn dominates Y's profile (78,91). Thus, a matching value of 80 indicates that X is preferable to Y. More generally, a matching response above 78 implies a preference for X; a matching response below 78 implies a preference for Y; and a matching response of 78 implies indifference between X and Y.

Formally, let (X_1, X_2) and (Y_1, Y_2) denote the values of options X and Y on attributes 1 and 2, respectively. Let V be the value of Y_1 for which the options are matched. We show that, under the standard assumptions, X is preferred to Y if and only if $V > Y_1$. Suppose $V > Y_1$, then (X_1, X_2) is equivalent to (V, Y_2) by matching, (V, Y_2) is preferred to (Y_1, Y_2) by dominance, hence, X is preferred to Y by transitivity. The other cases are similar.

We use the subscript 1 to denote the primary, or the more important dimension, and the subscript 2 to denote the secondary, or the less important dimension -- whenever they are defined. If neither option dominates the other, X denotes the option that is superior on the primary dimension and Y denotes the option that is superior on the secondary dimension. Thus, X_1 is better than Y_1 and Y_2 is better than X_2 .

Let C denote the percentage of respondents who chose X over Y, and let M denote the percentage of people whose matching response favored X over Y. Thus, C and M measure the tendency to decide according to the more important dimension in the choice and in the matching tasks, respectively. Assuming random allocation of subjects, procedure invariance implies $C = M$, whereas the prominence hypothesis implies $C > M$. As was shown above, the two contrasting predictions can be tested using aggregate between-subjects data.

To estimate M we presented four different groups of about 60 respondents each with the data of Problem 1, each with a different missing value, and we asked them to match the two candidates. The following table presents the values of M derived from the matching data for each of the four missing values, which are given in parentheses.

	1. Technical Knowledge	2. Human Relations
Candidate X	32% (86)	34% (76)
Candidate Y	42% (78)	25% (91)

There were no significant differences among the four matching groups, although M was greater when the missing value was low rather than high and when the missing value referred to the primary rather than to the secondary attribute ($M_1=37>30=M_2$). Overall, the matching data yielded $M = 34\%$ as compared with $C = 65\%$ obtained from choice ($p < .01$ by sign

test). This result supports the hypothesis that the more important attribute (e.g., technical knowledge) looms larger in choice than in matching.

In Problem 1 it is reasonable to assume -- as stated -- that for a production engineer, technical knowledge is more important than human relations. Our next problem (#2) had the same structure as Problem 1, except that the primary and secondary attributes were manipulated. Problem 2 dealt with the choice between candidates for the position of an advertising agent. The candidates were characterized by their scores on two dimensions: creativity and competence. One-half of the participants were told that "for the position in question, creativity is more important than competence", whereas the other half of the participants were told the opposite. As in Problem 1, most participants (65%, $N=60$) chose according to the more important attribute (either creativity or competence) but only 34% ($N=276$) of the matching responses favored X over Y. Again, M was higher for the primary than for the secondary attribute ($M_1 = 40 > 30 = M_2$), but all values of M were considerably smaller than C .

The next two problems involve policy choices concerning safety and the environment.

Problem 3 (Traffic Accidents)

About 600 people are killed each year in Israel in traffic accidents. The ministry of transportation investigates various programs to reduce the number of casualties. Consider the following two programs, described in terms of yearly costs (in millions of dollars) and the number of casualties per year that is expected following the implementation of each program.

	Expected number of casualties	Cost	[N=96]
Program X	500	\$55M	[67%]
Program Y	570	\$12M	[33%]

Which program do you favor?

The data on the right-hand side of the table indicate that two-thirds of the respondents chose Program X, which saves more lives at a higher cost per life saved. Two other groups matched the cost of either Program X or Program Y so as to make the two programs equally attractive. The overwhelming majority of matching responses in both groups (97%, N=133) favored the more economical Program Y that saves fewer lives. Problem 3 yields a dramatic violation of invariance: $C = 67\%$ but $M = 3\%$. This pattern follows from the prominence hypothesis, assuming the number of casualties is more important than cost. There was no difference between the groups that matched the high (\$55M) or the low (\$12M) values.

A similar pattern of responses was observed in Problem 4, which involves an environmental issue. The participants were asked to compare two programs for the control of a polluted beach:

Program X: A comprehensive program for a complete clean-up of the beach at a yearly cost of \$750,000 to the taxpayers.

Program Y: A limited program for a partial clean-up of the beach (that will not make it suitable for swimming) at a yearly cost of \$250,000 to the taxpayers.

Assuming the control of pollution is the primary dimension and the cost is secondary, we expect that the comprehensive program will be more popular in choice than in matching. This prediction was confirmed: $C = 47\%$ (N=95) and $M = 12\%$ (N=170). The matching data

were obtained from two groups of respondents who assessed the cost of each program so as to match the other. As in Problem 3, these groups gave rise to practically identical values of M .

Because the choice and the matching procedures are strategically equivalent, the rational theory of choice implies $C = M$. The two procedures, however, are not informationally equivalent because the missing value in the matching task is available in the choice task. To create an informationally equivalent task we modified the matching task by asking respondents, prior to the assessment of the missing value, (a) to consider the value used in the choice problem and indicate first whether it is too high or too low, and (b) to write down the value that they consider appropriate. In Problem 3, for example, the modified procedure reads as follows:

	Expected number of casualties	Cost
Program X	500	?
Program Y	570	\$12M

You are asked to determine the cost of Program X that would make it equivalent to Program Y.

- (a) Is the value of \$55M too high or too low?
- (b) What is the value you consider appropriate?

The modified matching procedure is equivalent to choice not only strategically but also informationally. Let C^* be the proportion of responses to question (a) that lead to the choice of X (e.g., "too low" in the above example). Let M^* be the proportion of (matching) responses to question (b) that favor option X (e.g., a value that exceeds \$55M in the above example). Thus, we may view C^* as choice in a matching context and M^* as matching in a

choice context. The values of C^* and M^* for Problems 1-4 are presented in Table 1, which yields the ordering $C > C^* > M^* > M$. The finding $C > C^*$ shows that merely framing the question in a matching context reduces the relative weight of the primary dimension. Conversely, $M^* > M$ indicates that placing the matching task after a choice-like task increases the relative weight of the primary dimension. Finally, $C^* > M^*$ implies a within-subject and within-problem violation of invariance in which the response to question (a) favors X while the response to question (b) favors Y. This pattern of responses indicates a failure, on the part of some subjects, to appreciate the logical connection between questions (a) and (b). It is noteworthy, however, that 86% of these inconsistencies follow the pattern implied by the prominence hypothesis.

Insert Table 1 about here

In the previous problems, the primary and the secondary attributes were controlled by the instructions, as in Problems 1 and 2, or by the intrinsic value of the attributes, as in Problems 3 and 4. (People generally agree that saving lives and eliminating pollution are more important goals than cutting public expenditures.) The next two problems involved benefit plans in which the primary and the secondary dimensions were determined by economic considerations.

Problem 5 (Benefit Plans)

Imagine that, as a part of a profit-sharing program, your employer offers you a choice between the following plans. Each plan offers two payments, in one year and in four years.

Table 1

Percentage of responses favoring the primary dimension under different elicitation procedures.
Sample sizes are given in parentheses.

Problem:	Dimensions		Choice C	Information Control C ^a	Information Control M ^a	Matching M	θ
	Primary	Secondary					
1. Engineer	Technical knowledge	Human relations	65 (63)	57 (156)	47 (151)	34 (252)	.82
2. Agent	Competence	Creativity	65 (60)	52 (155)	41 (152)	34 (276)	.72
3. Accidents	Casualties	Cost	67 (96)	50 (96)	18 (82)	3 (133)	.19
4. Pollution	Health	Cost	47 (95)	32 (103)	12 (94)	12 (170)	.45
5. Benefits	1 year	4 years	59 (56)			5 (46)	.86
6. Coupons	Books	Travel	66 (58)			10 (51)	.57
UNWEIGHTED MEAN			62	48	30	17	

	Payment in 1 year	Payment in 4 years	[N=36]
Plan X	\$2,000	\$2,000	[59%]
Plan Y	\$1,000	\$4,000	[41%]

Which plan do you prefer?

Because people surely prefer to receive a payment sooner rather than later, we assume that the earlier payment (in 1 year) acts as the primary attribute, and the later payment (in 4 years) acts as the secondary attribute. The results support the hypothesis: $C = 59\%$ ($N=56$) whereas $M = 5\%$ ($N=46$).

Problem 6 resembled Problem 5 except that the employee was offered a choice between two bonus plans consisting of a different combination of coupons for books and for travel. Because the former could be used in a large chain of bookstores, whereas the latter were limited to organized tours with a particular travel agency, we assumed that the book coupons would serve as the primary dimension. Under this interpretation, the prominence effect emerged again: $C = 66\%$ ($N=58$) and $M = 10\%$ ($N=51$).

Intrapersonal Tests

Slovic's (1975) original demonstration of the choice-matching discrepancy was based entirely on an intrapersonal analysis. In his design, the participants first matched the relevant option and then selected between the matched options at a later date. They were also asked afterwards to indicate the more important attribute in each case. The main results are summarized in Table 2, which presents for each choice problem the options, the primary and the

secondary attributes, and the resulting values of C. In every case, the value of M is 50% by construction.

Insert Table 2 about here

The results indicate that, in all problems, the majority of participants broke the tie between the matched option in the direction of the more important dimension as implied by the prominence hypothesis. This conclusion held regardless of whether the estimated missing value belonged to the primary or the secondary dimension, or whether it was the high value or the low value on the dimension. Note that the results of Table 2 alone could be explained by a shift in weight following the matching procedure (since the matching always preceded the choice) or by the application of a common tie-breaking procedure (since for each participant the two options were matched). These explanations, however, do not apply to the interpersonal data of Table 1.

On the other hand, Table 2 demonstrates the prominence effect within the data of each subject. The value of C was only slightly higher (unweighted mean: 78) when computed relative to each subject's ordering of the importance of the dimensions (as was done in the original analysis), presumably because of the general agreement among the respondents about which dimension was primary.

Table 2

Percentage of respondents (N=101) who chose between-matched alternatives (N=50%) according to the primary dimension. (After Slovic, 1975).

Alternatives	Dimensions		Choice Criterion	C
	Primary	Secondary		
1. Baseball players	Batting average	Home runs	Value to team	62
2. College applicants	Motivation	English	Potential success	69
3. Gifts	Cash	Coupons	Attractiveness	85
4. Typists	Accuracy	Speed	Typing ability	84
5. Athletes	Chin-ups	Push-ups	Fitness	68
6. Routes to work	Time	Distance	Attractiveness	75
7. Auto tires	Quality	Price	Attractiveness	67
8. TV Commercials	Number	Time	Annoyance	83
9. Readers	Comprehension	Speed	Reading Ability	79
10. Baseball teams	First place team	% of games Last place team	Won against Standing	86
UNWEIGHTED MEAN				76

THEORETICAL ANALYSIS

The data described in the previous section show that the primary dimensions of options loom larger in choice than in matching. This effect gives rise to a marked discrepancy between choice and matching, which violates the principle of procedure invariance assumed in the rational theory of choice. The prominence effect raises three general questions. First, what are the psychological mechanisms that underlie the choice-matching discrepancy and other failures of procedure invariance? Second, what changes in the traditional theory are required in order to accommodate these effects? Third, what are the implications of the present results to the analysis of choice in general, and the elicitation of preference in particular? The remainder of this paper is devoted to these questions.

The Compatibility Principle

One possible explanation of the prominence effect, introduced earlier in this paper, is the use of an essentially lexicographic procedure that favors the option that is superior on the primary dimension, provided the other option does not have a decisive advantage on the secondary dimension. This procedure is appealing because it allows the decision maker to resolve conflict on the basis of qualitative arguments (i.e., the prominence ordering of the dimensions) without establishing rates of exchange. The matching task, on the other hand, cannot be resolved in the same manner. Here, the decision maker must resort to quantitative comparisons in order to determine what interval on one dimension matches a given interval on the second dimension. This requires the setting of a common metric in which the attributes

are likely to be weighted more equally -- particularly when it is natural to match their ranges (e.g., salary and working conditions) or to compute cost per unit (e.g., the amount of money spent to save a single life).

It is instructive to distinguish between qualitative and quantitative arguments for choice. Qualitative, or ordinal, arguments are based on the ordering of the levels within each dimension, or on the prominence ordering of the dimensions. Quantitative, or cardinal, arguments are based on the comparison of value differences along the primary and the secondary dimensions. Thus, dominance and a lexicographic ordering are purely qualitative decision rules, whereas most other models of multiattribute choice make essential use of quantitative considerations.

The prominence effect indicates that qualitative considerations loom larger in the ordinal procedure of choice than in the cardinal procedure of matching, or equivalently, that quantitative considerations loom larger in matching than in choice. The prominence hypothesis, therefore, may be construed as an example of a more general principle of compatibility. According to this principle, the weight of any input component is enhanced by its compatibility with the output. The rationale for this principle is that noncompatibility (in content, scale, or display) between the input and the output requires additional mental transformations, which increase effort and error, and reduce impact (Fitts & Seeger, 1953; Wickens, 1984). We shall next review two studies of prediction and similarity that serve to illustrate the compatibility principle, and then develop a formal theory that encompasses a variety of compatibility effects, including the choice-matching discrepancy and the preference reversal phenomenon.

A simple demonstration of scale compatibility was obtained in a study by Griffin, Slovic and Tversky (1987). The subjects ($N=234$) were asked to predict the judgments of an admission committee of a small, selective college regarding several applicants. For each applicant the subjects received two items of information: a rank on Verbal SAT and the presence or absence of strong extra-curricular activities. The subjects were told that the admission committee ranks all 500 applicants and accepts about the top fourth. Half of the subjects predicted the rank assigned to each applicant, whereas the other half predicted whether each applicant was accepted or rejected.

The compatibility principle implies that the numerical data (i.e., rank SAT) will loom larger in the numerical prediction task, whereas the categorical data (i.e., the presence or absence of extra-curricular activities) will loom larger in the categorical prediction of acceptance or rejection. The results confirmed the hypothesis. For each pair of applicants, in which neither one dominates the other, we recorded the percentage of responses that favored the applicant with the higher SAT. Summing across all pairs, this value was 61.4% in the numerical prediction task and 44.6% in the categorical prediction task. The difference between the groups is highly significant. Evidently, the numerical data had more impact in the numerical task, while the categorical data had more impact in the categorical task. This result demonstrates the compatibility principle and reinforces the proposed interpretation of the choice-matching discrepancy in which the relative weight of qualitative arguments is larger in the qualitative method of choice than in the quantitative matching procedure.

In the previous example, compatibility was induced by the formal correspondence between the scales of the dependent and the independent variables. Compatibility effects can also be induced by semantic correspondence, as illustrated in the following example, taken from the study of similarity. In general, the similarity of objects (e.g., faces, people, letters) increases with the salience of the features they share, and decreases with the salience of the features that distinguish between them. More specifically, the contrast model (Tversky, 1977) represents the similarity of objects as a linear combination of the measures of their common and their distinctive features. Thus, the similarity of a and b is monotonically related to

$$\theta f(A \cap B) - g(A \Delta B)$$

where $A \cap B$ is the set of features shared by a and b , and $A \Delta B = (A - B) \cup (B - A)$ is the set of features that belong to one object and not to the other. The scales f and g are the measures of the respective feature sets.

The compatibility hypothesis suggests that common features loom larger in judgments of similarity than in judgments of dissimilarity, whereas distinctive features loom larger in judgments of dissimilarity than in judgments of similarity. As a consequence, the two judgments are not mirror images. A pair of objects with many common and many distinctive features could be judged as more similar, as well as more dissimilar, than another pair of objects with fewer common and fewer distinctive features. Tversky and Gati (1978) observed this pattern in the comparison of pairs of well-known countries with pairs of countries that were less known to the respondents. For example, most subjects in the similarity condition selected East Germany and West Germany as more similar to each other than Sri Lanka and Nepal, whereas most subjects in the dissimilarity condition selected East Germany and West

Germany as more different from each other than Sri Lanka and Nepal. These observations were explained by the contrast model with the added assumption that the relative weight of the common features is greater in similarity than in dissimilarity judgments (Tversky, 1977).

Contingent Tradeoff Models

In order to accommodate the compatibility effects observed in studies of preference, prediction and judgment, we need models in which the tradeoffs among inputs depend on the nature of the output. In the present section we develop a hierarchy of models of this type, called *contingent tradeoff models*. For simplicity, we investigate the two-dimensional case, and follow the choice-matching terminology. Extensions and applications are discussed later. It is convenient to use $A = \{a, b, c, \dots\}$ and $Z = \{z, y, x, \dots\}$ to denote the primary and the secondary attributes, respectively, whenever they are properly defined. The object set S is given by the product set $A \times Z$, with typical elements az , by , etc. Let \geq_c be the preference relation obtained by choice, and let \geq_m be the preference relation derived from matching.

As in the standard analysis of indifference curves we assume that each \geq_i , $i=c, m$, is a weak order, that is, reflexive, complete and transitive. We also assume that the space $S = A \times Z$ is connected, and that both \geq_c and \geq_m are continuous (see, e.g., Varian, 1984, Ch. 3). Finally, we assume that the levels of each attribute are consistently ordered, independent of the (fixed) level of the other attribute. That is,

$$az \geq_i bz \text{ iff } ay \geq_i by \text{ and } az \geq_i ay \text{ iff } bz \geq_i by, \quad i=c, m.$$

Under these assumptions there exist continuous functions F_i , G_i and U_i , defined on A , Z and $\mathbb{R} \times \mathbb{R}$, respectively, such that

$$(1) \quad az \geq_i by \text{ iff } U_i[F_i(a), G_i(z)] \geq U_i[F_i(b), G_i(y)]$$

where U_i , $i=c,m$, is monotonically increasing in each of its arguments.

Equation (1) imposes no constraints on the relation between choice and matching. Although our data show that the two orders do not generally coincide, it seems reasonable to suppose that they do coincide in unidimensional comparisons. Thus, we assume

$$az \geq_c bz \text{ iff } az \geq_m bz \text{ and } az \geq_c ay \text{ iff } az \geq_m ay.$$

It is easy to see that this condition is both necessary and sufficient for the monotonicity of the respective scales. That is,

$$(2) \quad F_c(b) \geq F_c(a) \text{ iff } F_m(b) \geq F_m(a) \text{ and}$$

$$G_c(z) \geq G_c(y) \text{ iff } G_m(z) \geq G_m(y).$$

Equations (1) and (2) define the general contingent tradeoff model that is assumed throughout. The other models discussed in this section are obtained by imposing further restrictions on the relation between choice and matching. The general model corresponds to a dual indifference map, that is, two families of indifference curves, one induced by choice and one induced by matching. A graphical illustration of a dual map is presented in Figure 1.

Insert Figure 1 about here

We next consider a more restrictive model that constrains the relation between the rates of substitution of the two attributes obtained by the two elicitation procedures. Let RS_i denote the rate of substitution between the two attributes (A and Z) according to procedure $i =$

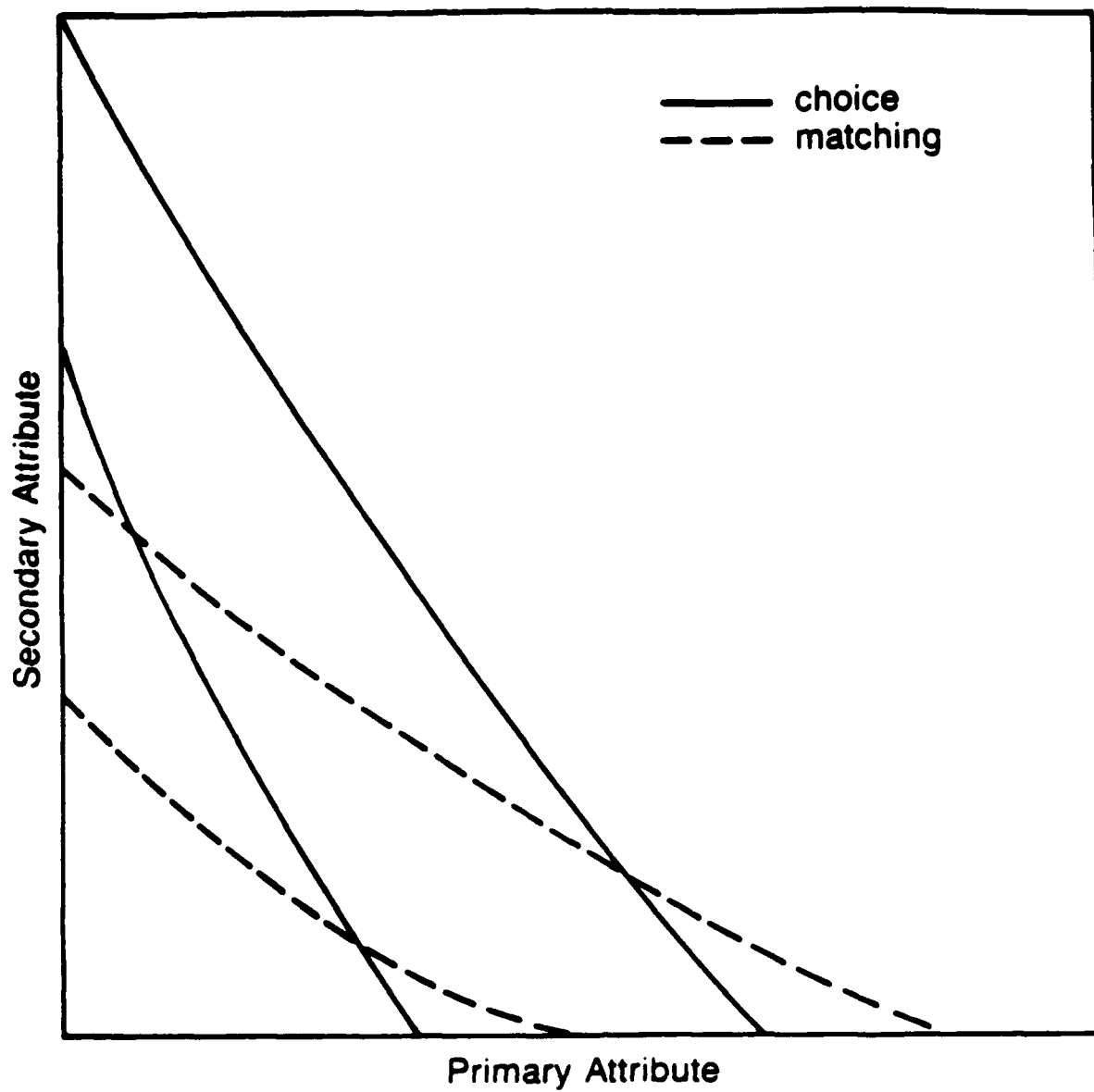


Figure 1. A dual indifference map induced by the general model (Equations 1 & 2).

c,m. Thus, $RS_i = F'_i/G'_i$, where F'_i and G'_i , respectively, are the partial derivatives of U_i with respect to F_i and G_i . Hence, $RS_i(az)$ is the negative of the slope of the indifference curve at the point az . Note that RS_i is a meaningful quantity even though F_i, G_i and U_i are only ordinal scales.

A contingent tradeoff model is *proportional* if the ratio of RS_c to RS_m is the same at each point. That is

$$(3) \quad RS_c(az)/RS_m(az) = \text{constant}.$$

Recall that in the standard economic model the above ratio equals 1. The proportional model assumes that this ratio is a constant, but not necessarily one. The indifference maps induced by choice and by matching, therefore, can be mapped into each other by multiplying the RS value at every point by the same constant.

Both the general and the proportional model impose few constraints on the utility functions U_i . In many situations preferences between multi-attribute options can be represented additively. That is, there exist functions F_i and G_i defined on A and Z , respectively, such that

$$(4) \quad az \geq_i by \text{ iff } F_i(a) + G_i(z) \geq F_i(b) + G_i(y), \quad i = c, m.$$

where F_i and G_i are interval scales with a common unit. The existence of such an additive representation is tantamount to the existence of a monotone transformation of the axes that maps all indifference curves into parallel straight lines.

Assuming the contingent tradeoff model, the following cancellation condition is both necessary and sufficient for additivity (4), see Krantz, Luce, Suppes, and Tversky (1971, Ch.6).

$ay \geq_i bx$ and $bz \geq_i cy$ imply $az \geq_i cx$, $i = c, m$.

If both proportionality and additivity are assumed we obtain a particularly simple form, called the *contingent weighting model*, in which the utility scales F_c, F_m and G_c, G_m are linearly related. In other words, there is a monotone transformation of the axes that *simultaneously* linearizes both sets of indifference curves. Thus, if both (3) and (4) hold there exist functions F and G defined on A and Z , respectively, and constants α_i, β_i , $i = c, m$, such that

$$(5) \quad az \geq_i by \quad \text{iff} \quad \alpha_i F(a) + \beta_i G(z) \geq \alpha_i F(b) + \beta_i G(y)$$

$$\text{iff} \quad F(a) + \theta_i G(z) \geq F(b) + \theta_i G(y)$$

where $\theta_i = \beta_i / \alpha_i$. In this model, therefore, the indifference maps induced by choice and by matching are represented as two sets of parallel straight lines that differ only in slope $-\theta_i$, $i = c, m$, see Figure 2. We are primarily interested in the ratio $\theta = \theta_c / \theta_m$ of these slopes.

Insert Figure 2 about here

Because the rate of substitution in the additive model is constant, it is possible to test proportionality (3) without assessing local RS_i . In particular, the contingent weighting model (5) implies the following interlocking condition

$$ax \geq_c bw, \quad dw \geq_c cx, \quad \text{and} \quad by \geq_m az \quad \text{imply} \quad dy \geq_m cz$$

and the same holds when the attributes (A and Z) and the orders (\geq_c and \geq_m) are interchanged. Figure 3 presents a graphic illustration of this condition.

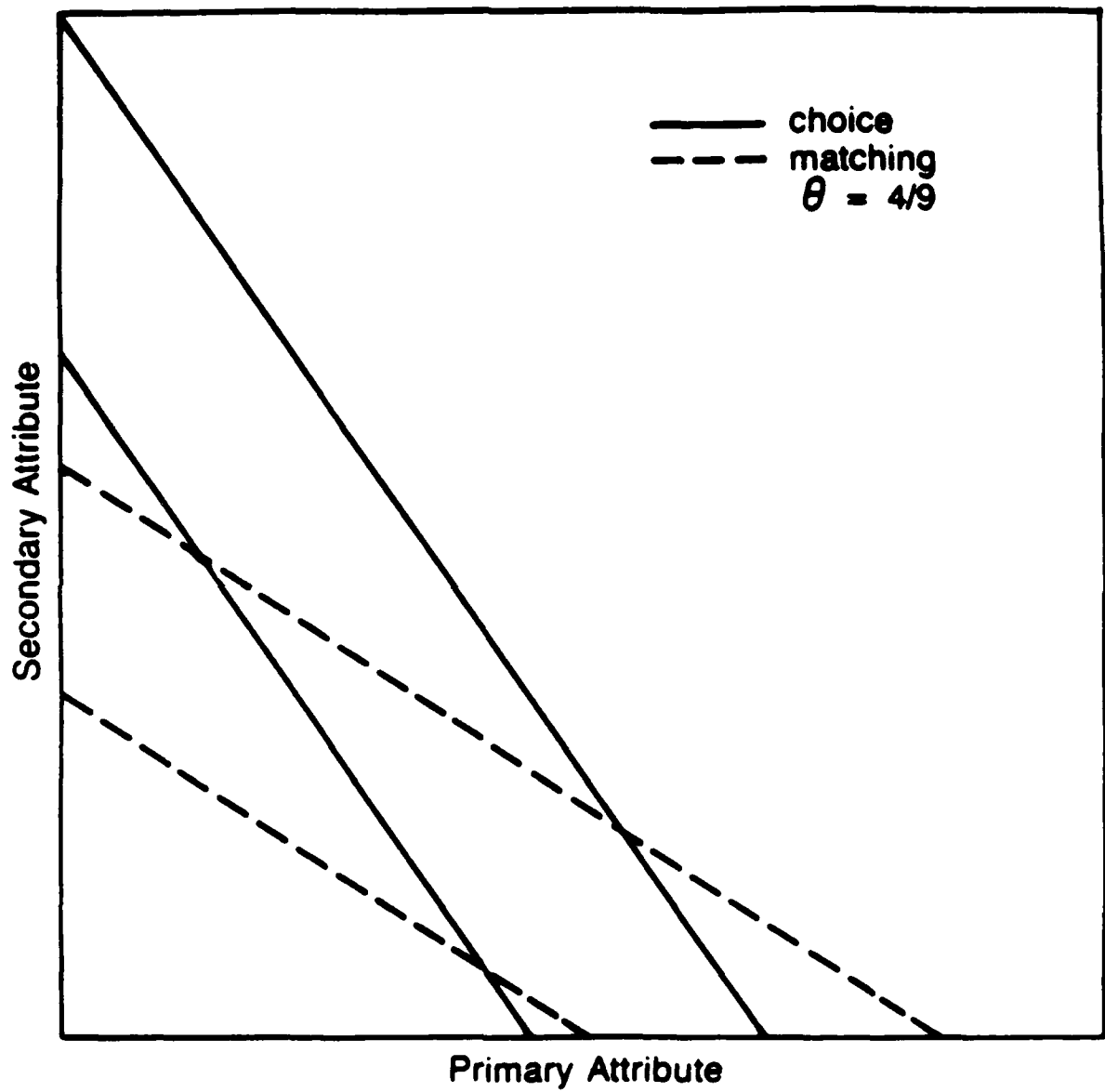


Figure 2. A dual indifference map induced by the additive model (4).

Insert Figure 3 about here

The interlocking condition is closely related to triple cancellation, or the Reidemeister condition (see Krantz et al, 1971, 6.2.1), tested by Coombs, Bezembinder and Goode (1967). The major difference between the assumptions is that the present interlocking condition involves two orders rather than one. This condition says, in effect, that the intradimensional ordering of A-intervals or Z-intervals is independent of the method of elicitation. This can be seen most clearly by deriving the interlocking condition from the contingent weighting model. From the hypotheses of the condition, in conjunction with the model, we obtain

$$F(a) + \theta_c G(x) \geq F(b) + \theta_c G(w) \text{ or } \theta_c [G(x) - G(w)] \geq F(b) - F(a)$$

$$F(d) + \theta_c G(w) \geq F(c) + \theta_c G(x) \text{ or } F(d) - F(c) \geq \theta_c [G(x) - G(w)]$$

$$F(b) + \theta_m G(y) \geq F(a) + \theta_m G(z) \text{ or } F(b) - F(a) \geq \theta_m [G(z) - G(y)]$$

The right-hand inequalities yield

$$F(d) - F(c) \geq \theta_m [G(z) - G(y)] \text{ or } F(d) + \theta_m G(y) \geq F(c) + \theta_m G(z),$$

hence $dy \geq_m cz$ as required.

The interlocking condition is not only necessary but also sufficient because it implies that the inequalities

$$F_i(d) - F_i(c) \geq F_i(b) - F_i(a) \text{ and}$$

$$G_i(z) - G_i(y) \geq G_i(x) - G_i(w)$$

are independent of $i=c,m$. By the uniqueness of the scales, therefore, there exist functions F

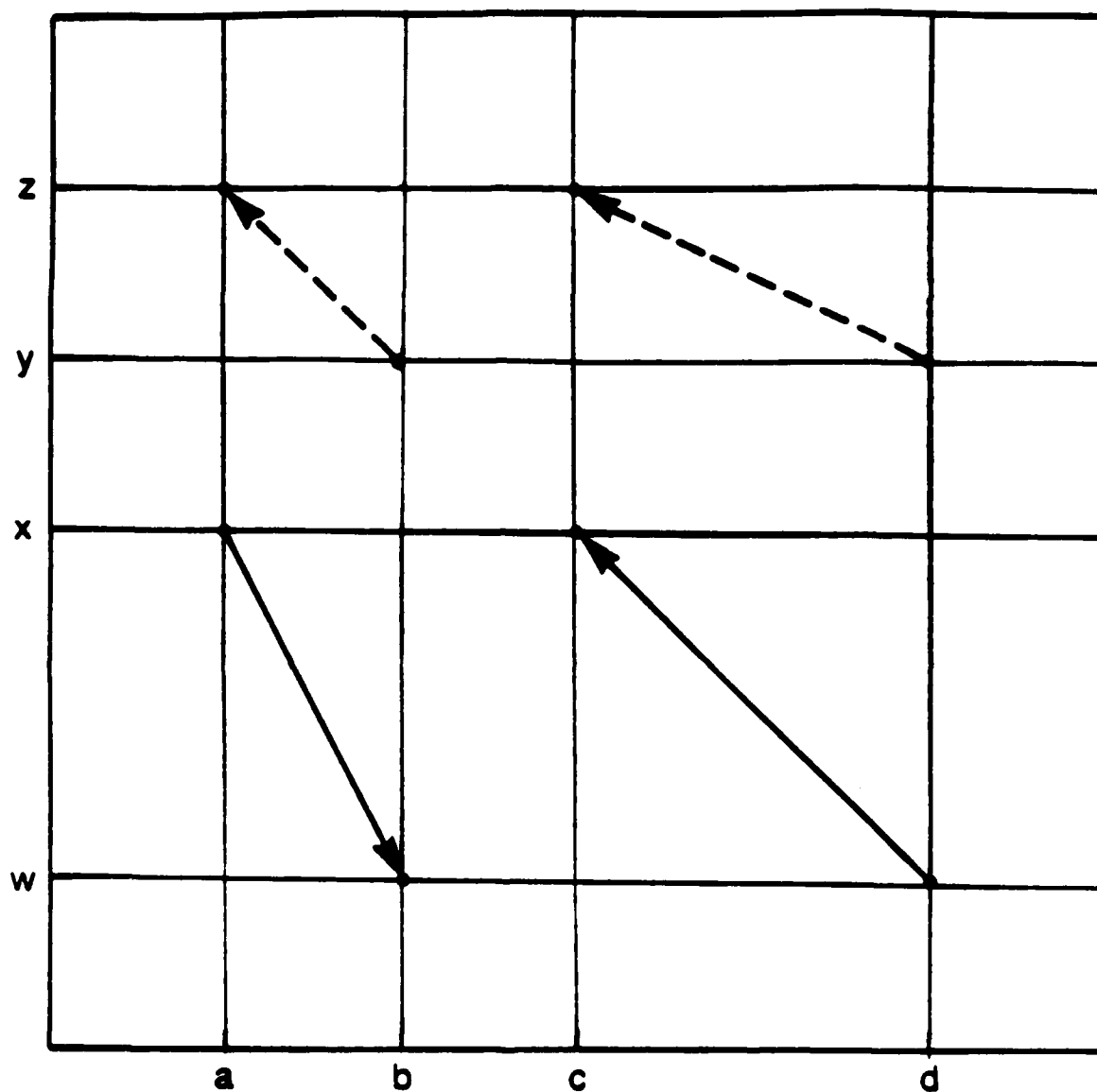


Figure 3. A graphic illustration of the interlocking condition where arrows denote preferences.

and G and constants α_i, β_i such that

$$az \geq_i by \text{ iff } \alpha_i F(a) + \beta_i G(z) \geq \alpha_i F(b) + \beta_i G(y).$$

Thus, we have established the following result.

Theorem: Under the general model (1 & 2), the contingent weighting model (5) holds iff the interlocking condition is satisfied.

Perhaps the simplest, and most restrictive, instance of (5) is the case where A and Z are sets of real numbers and both F and G are linear. In this case, the weighting model reduces to

$$\begin{aligned} (6) \quad az \geq_i by \text{ iff } \alpha_i a + \beta_i z &\geq \alpha_i b + \beta_i y \\ \text{iff } a + \theta_i z &\geq b + \theta_i y, \quad \theta_i = \beta_i / \alpha_i, \quad i = c, m. \end{aligned}$$

The hierarchy of contingent tradeoff models is presented in Figure 4, where implications are denoted by arrows, and the (ordinal) assumptions of each model are given in brackets.

Insert Figure 4 about here

In the following section we apply the contingent weighting model to several sets of data and estimate the relative weights of the two attributes under different elicitation procedures. Naturally, all the models of Figure 4 are consistent with the compatibility hypothesis. We use the linear model (6) because it is highly parsimonious and reduces the estimation to a single parameter $\theta = \theta_c / \theta_m$. If linearity of scales and/or additivity of attributes are seriously violated in the data, higher models in the hierarchy should be used. The

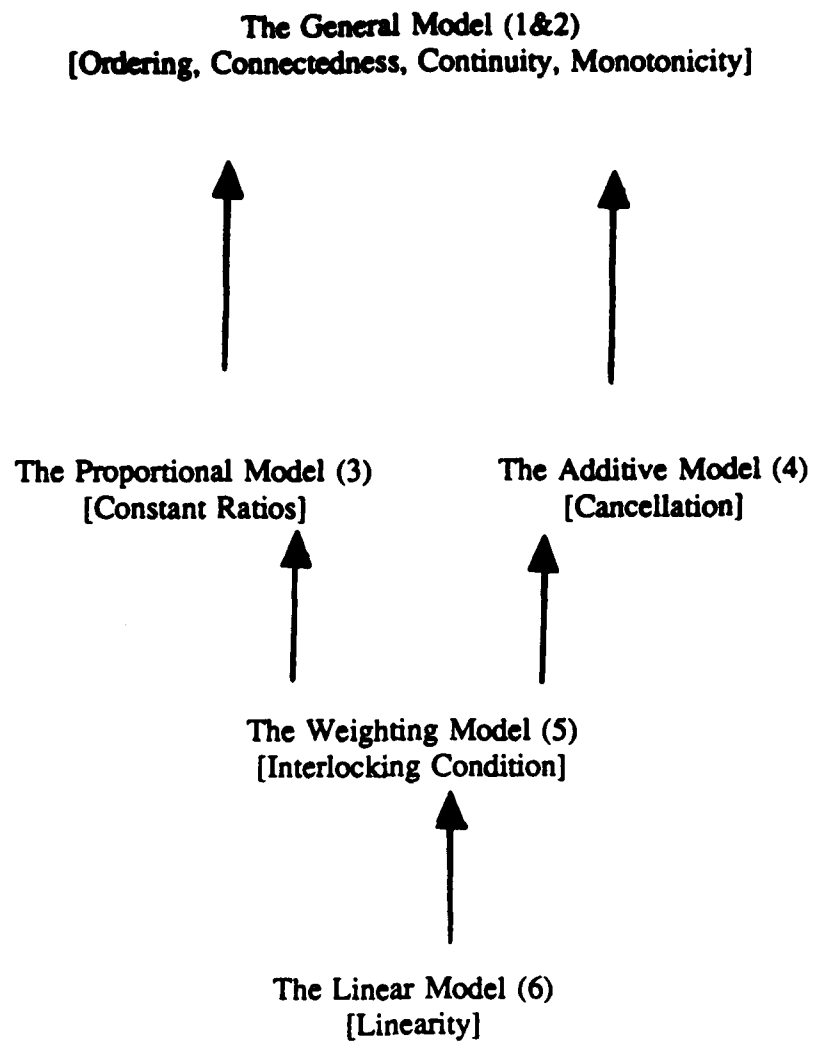


Figure 4. A hierarchy of contingent preference models. Implications are denoted by arrows and assumptions are given in brackets.

contingent weighting model can be readily extended to deal with several elicitation methods and three or more attributes. Extensions involving nonadditive composition functions lie beyond the scope of the present paper.

APPLICATIONS

The Choice-Matching Discrepancy

We first compute $\theta = \theta_c/\theta_m$ from the choice and matching data, summarized in Table 1. Let $C(az,by)$ be the percentage of respondents who chose az over by , and let $M(az,by)$ be the percentage of respondents whose matching response favored az over by . Consider the respondents who matched the options by adjusting the second component of the second option. Because different respondents produced different values of the missing component (y), we can view $M(az,b.)$ as a (decreasing) function of the missing component. Let \bar{y} be the value of the second attribute for which $M(az,b\bar{y}) = C(az,by)$.

If the choice and the matching agree \bar{y} should be equal to y , whereas the prominence hypothesis implies that \bar{y} lies between y and z (i.e., $|z-y| > |z-\bar{y}|$). To estimate θ from these data, we introduce an additional assumption that relates the linear model (6) to the observed percentage of responses.

$$(7) \quad M(az,b\bar{y}) = C(az,by) \text{ iff}$$

$$(a + \theta_m z) - (b + \theta_m \bar{y}) = (a + \theta_c z) - (b + \theta_c y) \text{ iff}$$

$$\theta_m(z - \bar{y}) = \theta_c(z - y).$$

Under this assumption we can compute

$$\theta = \theta_c / \theta_m = (z - \bar{y}) / (z - y),$$

and the same analysis applies to the other three components (i.e., \bar{a} , \bar{b} , and \bar{z}).

We applied this method to the aggregate data from Problems 1 to 6. The average values of θ , across subjects and components, are displayed in Table 1 for each of the six problems. The values of $\theta = \theta_c / \theta_m$ are all less than unity, as implied by the prominence hypothesis. Note that θ provides an alternative index of the choice-matching discrepancy that is based on (6) and (7) -- unlike the difference between C and M that does not presuppose any measurement structure.

Prediction of Performance

We next employ the contingent weighting model to analyze the effect of scale compatibility observed in a study of the prediction of students' performance, conducted by Griffin, et al (1987). The subjects (N=234) in this study were asked to predict the performance of ten students in a course (e.g., History) on the basis of their performance in two other courses (e.g., Philosophy and English). For each of the ten students, the subjects received a grade in one course (from A+ to D), and a class rank (from 1 to 100) in the other course. One-half of the respondents were asked to predict a grade while the other half were asked to predict class rank. The courses were counterbalanced across respondents. The compatibility principle implies that a given predictor (e.g., grade in Philosophy) will be given more weight when the predicted variable is expressed on the same scale (e.g., grade in History) than when it is expressed on a different scale (e.g., class rank in History). The relative weight of grades to ranks, therefore, will be higher in the group that predicts grades than in the group that predicts

ranks.

Let (r_i, g_j) be a student profile with rank i in the first course and grade j in the second. Let r_{ij} and g_{ij} denote, respectively, the predicted rank and grade of that student. The ranks range from 1 to 100, and the grades were scored as: A+=10, A=9, ..., D=1. Under the linear model (6), we have

$$r_{ij} = \alpha_r r_i + \beta_r g_j \quad \text{and} \quad g_{ij} = \alpha_g r_i + \beta_g g_j$$

By regressing the ten predictions of each respondent against the predictors, r_i and g_j , we obtained for each subject in the rank condition an estimate of $\theta_r = \beta_r/\alpha_r$, and for each subject in the grade condition an estimate of $\theta_g = \beta_g/\alpha_g$. These values reflect the relative weight of grades to ranks in the two prediction tasks. As implied by the compatibility hypothesis, the values of θ_g were significantly higher than the values of θ_r , $p < .001$ by a Mann-Whitney test.

Insert Figure 5 about here

Figure 5 represents each of the 10 students as a point in the rank \times grade plane. The slopes of the two lines, θ_r and θ_g , correspond to the relative weights of grade to rank estimated from the average predictions of ranks and grades, respectively. The multiple correlation between the inputs (r_i, g_j) and the average predicted scores was .99 for ranks and .98 for grades, indicating that the linear model provides a good description of the aggregate data. Recall that in the contingent weighting model, the predicted scores are given by the perpendicular projections of the points onto the respective lines, indicated by notches. The two

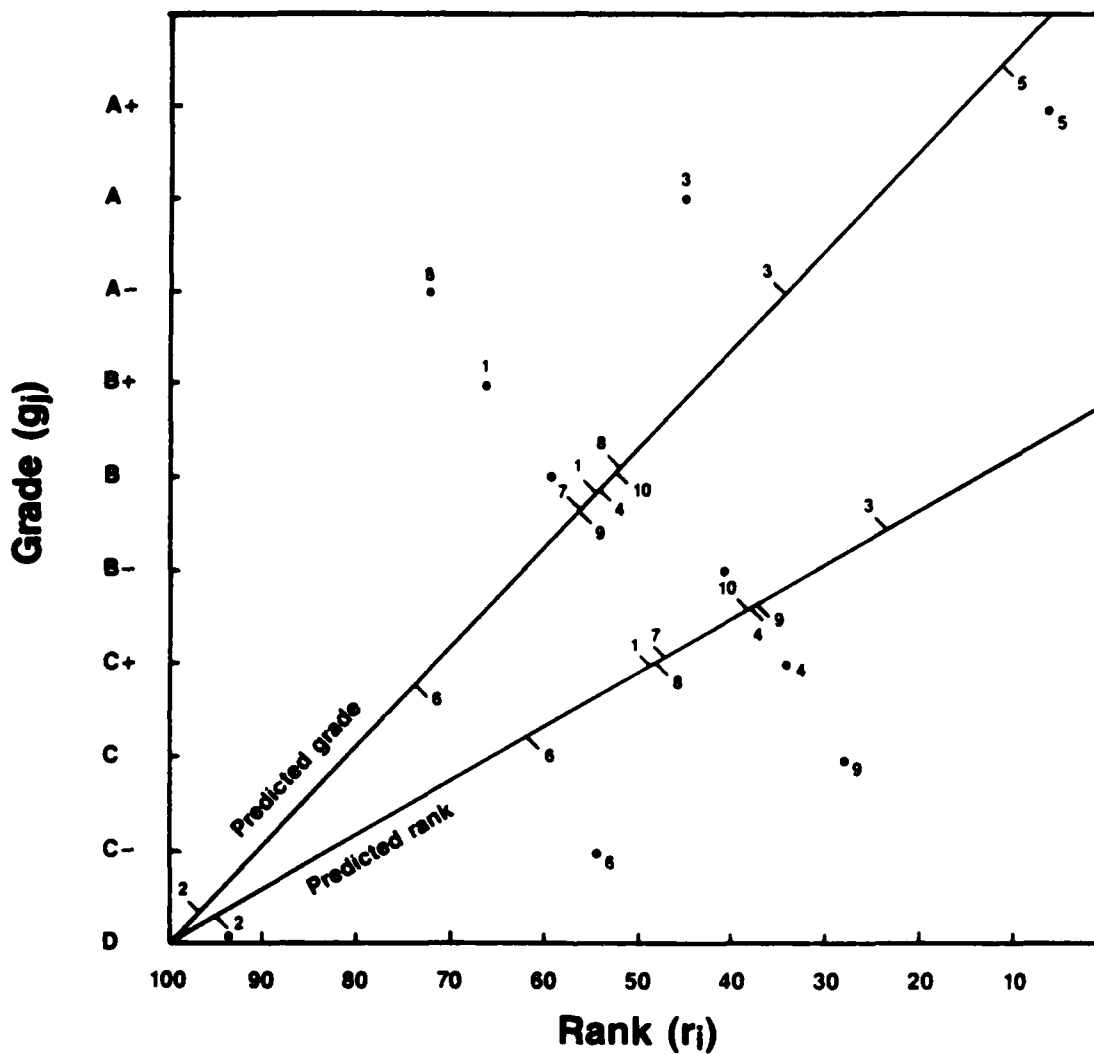


Figure 5. Contingent weighting representation of predicted ranks and grades. The dots characterize the input information for each of the ten students. The slopes of the two lines correspond to the relative weight of grades to ranks in the two prediction tasks.

lines, then, are orthogonal to the equal-value sets defined by the two tasks. The figure shows that grades and ranks were roughly equally weighted in the prediction of grades ($\theta_g = 1.06$), but grades were given much less weight than ranks in the prediction of ranks ($\theta_r = .58$). As a consequence, the two groups generated different ordering of the students. For example, the predicted rank of Student #9 was higher than that of Student #8, but the order of the predicted grades was reversed. Note that the numbered points in Figure 5 represent the design, not the data. The discrepancy between the two orderings is determined jointly by the angle between the lines that is estimated from subjects' predictions, and by the correlation between the two dimensions that is determined by the design.

These data suggest a more detailed account based on a process of anchoring and adjustment (Slovic & Lichtenstein, 1971; Tversky & Kahneman, 1974). According to this heuristic, the subject uses the score on the compatible attribute (either rank or grade) as an anchor, and adjusts it upward or downward on the basis of the other score. Because adjustments are generally insufficient, the compatible attribute is overweighted. Although the use of anchoring and adjustment probably contribute to the phenomenon in question, Griffin et al (1987) found a significant compatibility effect even when the subject only predicted which of the two students would obtain a higher grade (or rank), without making any numerical prediction that calls for anchoring and adjustment.

Preference Reversals

The contingent weighting model (5) and the compatibility principle can also be used to explain the well-known preference reversals discovered by Lichtenstein and Slovic (1971; see also Slovic and Lichtenstein, 1968, 1983). These investigators compared two types of bets with comparable expected values -- an H bet that offers a high probability of winning a relatively small amount of money (e.g., 32/36 chance to win \$4) and an L bet that offers a low probability of winning a moderate amount of money (e.g., 9/36 chance to win \$40). The results show that people generally choose the H bet over the L bet (i.e., $H >_c L$) but assign a higher cash equivalent to the L bet than to the H bet (i.e., $C_L > C_H$, where C_L and C_H are the amounts of money that are as desirable as L and H respectively). This pattern of preferences, which is inconsistent with the theory of rational choice, has been observed in numerous experiments, including a study conducted on the floor of a Las Vegas casino (Lichtenstein & Slovic, 1973), and it persists even in the presence of monetary incentives designed to promote consistent responses (Grether & Plott, 1979).

Although the basic phenomenon has been replicated in many studies, the determinants of preference reversals and their causes have remained elusive heretofore. It is easy to show that the reversal of preferences implies either intransitive choices or a choice-pricing discrepancy (i.e., a failure of invariance), or both. In order to understand this phenomenon, it is necessary to assess the relative contribution of these factors because they imply different explanations. To accomplish this goal, however, one must extend the traditional design and include, in addition to the bets H and L, a cash amount X that is compared to both. If procedure invariance holds and preference reversals are due to intransitive choices, then we should obtain the cycle $L >_c X >_c H >_c L$. If, on the other hand, transitivity holds and prefer-

ence reversals are due to an inconsistency between choice and pricing, then we should obtain either $X >_c L$ and $C_L > X$, or $H >_c X$ and $X > C_H$. The first pattern indicates that L is *overpriced* relative to choice, and the second pattern indicates that H is *underpriced* relative to choice. Recall that $H >_c X$ refers to the choice between the bet H and the sure thing X , while $X > C_H$ refers to the ordering of cash amounts.

Following this analysis Tversky, Slovic and Kahneman (1987) conducted an extensive study of preference reversals, using 18 triples (H, L, X) that cover a wide range of probabilities and payoffs. A detailed analysis of response patterns showed that, by far, the most important determinant of preference reversals is the overpricing of L . Intransitive choices and the underpricing of H play a relatively minor role, each accounting for less than 10% of the total number of reversals. Evidently, preference reversals represent a choice-pricing discrepancy induced by the compatibility principle: because pricing is expressed in monetary units, the payoffs loom larger in pricing than in choice.

We next apply the contingent weighting model to a study reported by Tversky et al (1987) in which 179 participants (i) chose between 6 pairs consisting of an H bet and an L bet, (ii) rated the attractiveness of all 12 bets, and (iii) determined the cash equivalent of each bet. In order to provide monetary incentives and assure the strategic equivalence of the three methods, the participants were informed that a pair of bets would be selected at random, and that they would play the member of the pair that they had chosen, or the bet that they had priced or rated higher. The present discussion focuses on the relation between pricing and rating, which can be readily analyzed using multiple regression. In general, rating resembles choice in favoring the H bets, in contrast to pricing that favors the L bets. Note that in rating

and pricing each gamble is evaluated separately, whereas choice (and matching) involve a comparison between gambles. Because the discrepancy between rating and pricing is even more pronounced than that between choice and pricing, the reversal of preferences cannot be explained by the fact that choice is comparative while pricing is singular. For further discussions of the relation between rating, choice and pricing, see Goldstein and Einhorn (1987), and Schkade and Johnson (1987).

We assume that the value of a simple prospect (q,y) is approximated by a multiplicative function of the probability q and the payoff y . Thus, the logarithms of the pricing and the rating can be expressed by

$$(8) \quad \theta_i \log y + \log q, \quad i = r, p,$$

where θ_r and θ_p denote the relative weight of the payoff in the rating and in the pricing tasks, respectively. Note that this model implies a power utility function with an exponent θ_i . The average transformed rating and pricing responses for each of the 12 bets were regressed, separately, against $\log q$ and $\log y$. The multiple correlations were .96 and .98 for the ratings and the pricing, respectively, indicating that the relation between rating and pricing can be captured, at least in the aggregate data, by a very simple model with a single parameter.

Insert Figure 6 about here

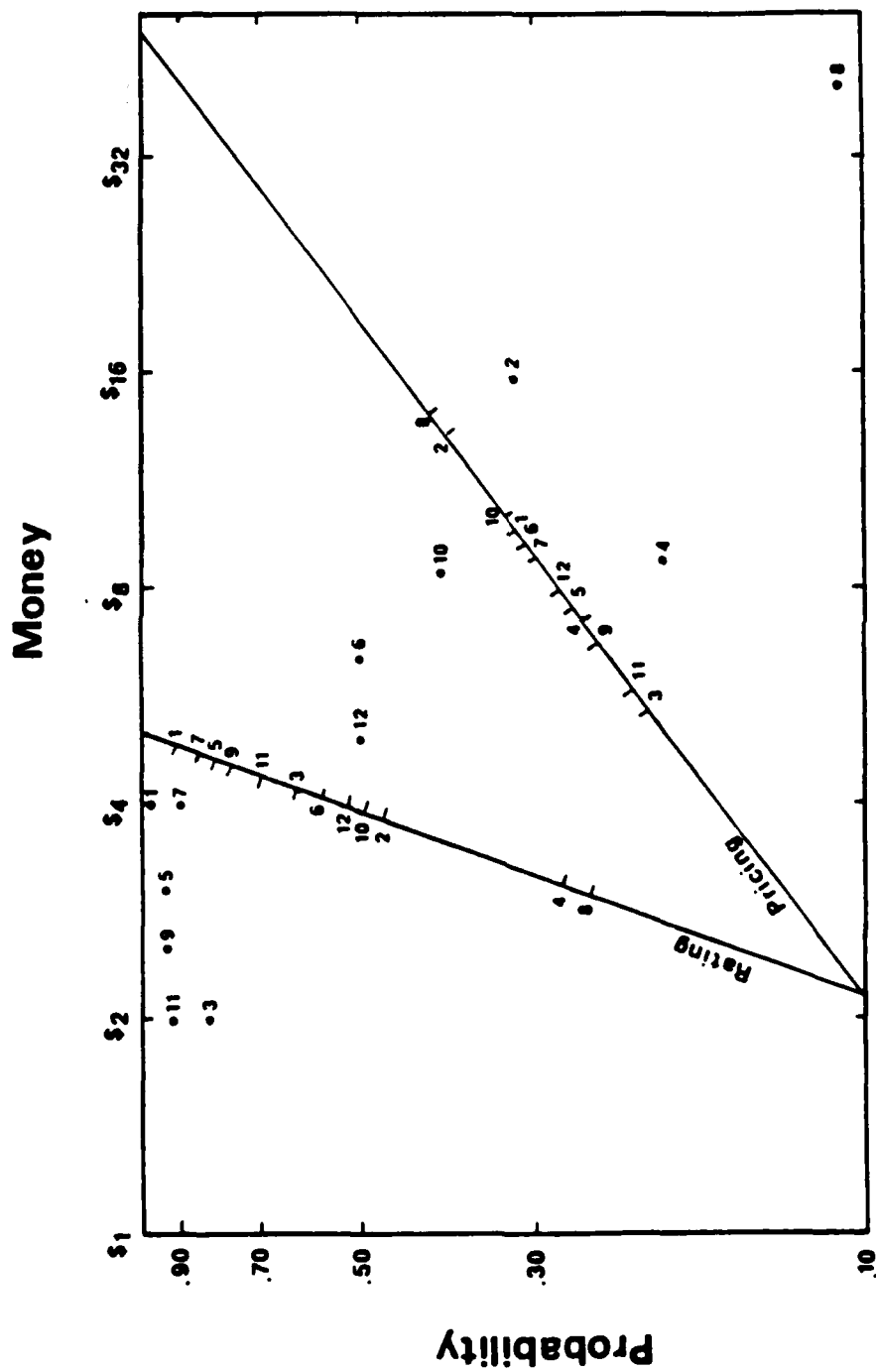


Figure 6. Contingent weighting representation of rating and pricing. The dots characterize the six H bets and six L bets denoted by odd and even numbers, respectively, in logarithmic coordinates. The slopes of the two lines correspond to the weight of money relative to probability in rating and in pricing.

Figure 6 represents each of the 12 bets as a (numbered) point in the plane whose coordinates are probability and money, plotted on a logarithmic scale. The rating and pricing lines in the figure are perpendicular to the respective sets of linear indifference curves, see Figure 2. Hence, the projections of each bet on the two lines (denoted by notches) correspond to their values derived from rating and pricing, respectively. The angle between these lines equals the smaller angle between the intersecting families of indifference curves. Figure 6 reveals a dramatic difference between the slopes: $\theta_r = 2.7$, $\theta_p = .75$, hence $\theta = \theta_p/\theta_r = .28$. Indeed, these data give rise to a negative correlation ($r = -.30$) between the rating and the pricing, yielding numerous reversals of the ordering of the projections on the two lines. For example, the most extreme L bet (#8) has the lowest rating and the highest cash equivalent in the set.

The preceding analysis shows that the compatibility principle, incorporated into the contingent weighting model, provides a simple account of the well-known preference reversals. It also yields new predictions, which have been confirmed in a recent study. Note that if preference reversals are caused primarily by the overweighting of payoffs in the pricing task, then the effect should be much smaller for nonmonetary payoffs. Indeed, Tversky, et al (1987) found that the use of nonmonetary payoffs (e.g., a dinner for two at a very good restaurant or a free weekend at a coastal resort) reduced the incidents of preference reversals by more than one-half. Furthermore, according to the present analysis, preference reversals are not limited to risky prospects. Tversky, et al (1987) constructed riskless options of the form $(\$x, t)$ that offers a payment of $\$x$ at some future time, t (e.g., three years from now). Subjects chose between such options, and evaluated their cash equivalents. The cash equivalent

(or the price) of the option $(\$x, t)$ is the amount of cash, paid immediately, that is as attractive as receiving $\$x$ at time t . Because both the price and the payment are expressed in dollars, compatibility implies that the payment will loom larger in pricing than in choice. This prediction was confirmed. Subjects generally chose the option that paid sooner, and assigned a higher price to the option that offered the larger payment. For example, 87% of the subjects ($N=156$) preferred \$2500 in 5 years over \$3550 in 10 years, but 76% assigned a higher price to the second option. Thus, the replacement of risk by time gives rise to a new type of reversals. Evidently, preference reversals are determined primarily by the compatibility between the price and the payoff, regardless of the presence or absence of risk.

We conclude this section with a brief discussion of alternative accounts of preference reversals proposed in the literature. One class of comparative theories, developed by Fishburn (1984,1985) and Loomes and Sugden (1982,1983), treat preference reversals as intransitive choices. As was noted above, however, the intransitivity of choice accounts for only a small part of the phenomenon in question, hence these theories do not provide a fully satisfactory explanation of preference reversals. A different model, called expression theory, has been developed by Goldstein and Einhorn (1987). This model is a special case of the contingent tradeoff model, defined by Equations (1) and (2). It differs from the present treatment in that it focuses on the expression of preferences rather than on the evaluation of prospects. Thus, it attributes preference reversals to the mapping of subjective value onto the appropriate response scale, not to the compatibility between the input and the output. As a consequence, this model does not imply many of the compatibility effects described in this paper, such as the contingent weighting of grades and ranks in the prediction of students' performance, the

marked reduction in preference reversals with nonmonetary payoffs, and the differential weighting of common and of distinctive features in judgments of similarity and dissimilarity.

A highly pertinent analysis of preference reversals based on attention and anchoring data was proposed by Schkade and Johnson (1987). Using a computer-controlled experiment in which the subject can see only one component of each bet at a time, these investigators measured the amount of time spent by each subject looking at probabilities and at payoffs. The results showed that in the pricing task, the percentage of time spent on the payoffs was significantly greater than that spent on probabilities, whereas in the rating task, the pattern was reversed. This observation supports the hypothesis, suggested by the compatibility principle, that subjects attended to payoffs more in the pricing task than in the rating task. Schkade and Johnson also instructed their subjects to respond by first moving the cursor to the relevant ball park and then adjusting its setting appropriately. They observed that in the pricing task, the initial settings were substantially higher for L bets than for H bets, whereas for rating the initial settings were higher for H bets than for L bets. The reversals of preference observed in this study can thus be explained by insufficient adjustments (Slovic & Lichtenstein, 1971; Tversky & Kahneman, 1974) of the self-generated anchors. The production of these anchors, however, appears to be governed by compatibility. Recall that the range of the response scale in the pricing task is perfectly correlated with the payoff, whereas the range of the rating scale (0 to 20) is bounded like the probability scale. By compatibility, the payoff is expected to loom larger in pricing than in rating, whereas the probability is expected to loom larger in rating than in pricing. The process data obtained by Schkade and Johnson permits a more refined analysis of the roles of anchoring and adjustment, and of compatibility in the elicita-

tion of preferences. For further examples and discussions of elicitation biases in risky choice, see Fischer, Damodaran, Laskey, and Lincoln (1987), and Hershey and Schoemaker (1985).

DISCUSSION

The extensive use of rational theories of choice (e.g., the expected utility model or the theory of revealed preference) as descriptive models (e.g., in economics, management and political science) has stimulated the experimental investigation of the descriptive validity of the assumptions that underlie these models. Perhaps the most basic assumption of the rational theory of choice is the principle of invariance (Kahneman and Tversky, 1984) or extensionality (Arrow, 1982), which states that the relation of preference should not depend on the description of the options (description invariance) or on the method of elicitation (procedure invariance). However, experiments have shown that alternative framing of the same options can lead to drastic changes in choice (e.g., Tversky and Kahneman, 1986). The present studies provide evidence against the procedure invariance principle by demonstrating a systematic discrepancy between choice and matching, as well as between rating and pricing. In this section we discuss the main findings, and explore their theoretical and practical implications.

In the first part of the paper we showed that the more important dimension of a decision problem looms larger in choice than in matching. This discrepancy between choice and matching is systematic and robust, although it is probably not universal. We addressed this phenomenon at three levels of analysis: first, we proposed a heuristic account of the choice-matching discrepancy in terms of an essentially lexicographic procedure; second, we related

this procedure to the general notion of input-output compatibility; and third, we developed the formal theory of contingent weighting that provides a simple representation of the prominence effect as well as other compatibility phenomena, such as preference reversals.

Although the prominence effect was observed in a variety of settings using both intrapersonal and interpersonal comparisons, its boundaries are left to be explored. How does it extend to options that vary on a larger number of attributes? Is the choice-matching discrepancy limited to preference, or does it apply to other judgmental or perceptual tasks? The present results and analysis indicate that the prominence effect is not limited to preferential choice, but it is not clear whether it applies to psychophysics. Perceived loudness, for example, depends primarily on intensity and to a lesser degree on frequency. The prominence hypothesis could be tested in such a context. We conjecture that the choice-matching discrepancy is likely to arise in situations where the required judgment is complex rather than elementary, and where the stimulus components are physically distinct and psychologically separable (see, e.g., Tversky & Gati, 1982).

The finding that the qualitative information about the ordering of the dimensions looms larger in the ordinal method of choice than in the cardinal method of matching has been construed as an instance of the compatibility principle. This principle states that stimulus components that are compatible with the response are weighted more heavily than those that are not, presumably because the latter require additional mental transformations that produce error and reduce the diagnosticity of the information. This effect may be induced by the nature of the information (e.g., ordinal vs. cardinal), by the response scale (e.g., grades vs. ranks), or by the affinity between inputs and outputs (e.g., common features loom larger in similarity than

in dissimilarity judgments). Thus, compatibility provides a common explanation to many phenomena of judgment and choice although the exact mechanisms by which it works remain to be determined.

The preceding discussion raises the intriguing normative question as to which method, choice or matching, better reflects peoples' "true" preferences. Put differently, do people overweight the primary dimension in choice or do they underweight it in matching? Without knowing the "correct" weighting it is unclear how to answer this question, but the following study provides some relevant data. The participants in a decision-making seminar performed both choice and matching in the traffic-accident problem, described earlier (Problem 3). The two critical (choice and matching) questions were embedded in a questionnaire that included similar questions with different numerical values. The majority of the respondents (21 out of 32) gave inconsistent responses that conformed to the prominence hypothesis. After the session, each participant was interviewed and confronted with his or her answers. The subjects were surprised to discover that their responses were inconsistent and they offered a variety of explanations, some of which resemble the prominence hypothesis. One participant, for example, said "When I have to choose between programs I go for the one that saves more lives because there is no price for human life. But when I have to match the programs I pay much more attention to the money." When asked to reconsider their answers all respondents modified their matching in the direction of their choice, and nearly one-half also modified their choice in the direction of their matching. This observation suggests the possibility that choice and matching are both biased in opposite directions. However, it may reflect a routine compromise between inconsistent responses, rather than the result of a critical reassessment.

Real-world decisions can sometimes be framed either as a direct choice (e.g., should I buy the used car at this price?) or as a pricing decision (e.g., what is the most I should pay for that used car?). Our findings suggest that the answers to the two questions are likely to diverge. Consider, for example, a medical decision problem where the primary dimension is the probability of survival and the secondary dimension is the cost associated with treatment or diagnosis. According to the present analysis, people are likely to choose the option that offers the higher probability of survival with relatively little concern for cost. When asked to price a marginal increase in the probability of survival, however, people are expected to appear less generous. It has been suggested (V. Fuchs, personal communication) that health insurance plans are attractive, among other reasons, because they relieve people from the agonizing decision of how much money to spend on medical treatment of a family member. The choice-matching discrepancy may also arise in resource allocation and budgeting decisions. The prominence hypothesis suggests that the most important item in the budget (e.g., health) will tend to dominate a less important item (e.g., culture) in a direct choice between two allocations. On the other hand, the less important item is expected to fare much better in a matching procedure.

The lability of preferences implied by the demonstrations of framing and elicitation effects raises difficult questions concerning the assessment of preferences and values. In the classical analysis, the relation of preference is inferred from observed responses (e.g., choice, matching) and is assumed to reflect the decision maker's underlying utility or value. But if different elicitation procedures produce different orderings of options, how can preferences and values be defined? And in what sense do they exist? To be sure, people make choices,

set prices, rate options and even explain their decisions to others. Thus, preferences can be said to exist as observed data. If these data, however, do not satisfy the elementary requirements of invariance, it is unclear how to define a relation of preference that can serve as a basis for the measurement of value.

In a well-known article entitled "De Gustibus Non Est Disputandum" (there is no accounting for taste), economists Gary Becker and George Stigler (1977) argued that preferences are not only well-defined (as economists normally assume), they are also constant across people and unchanging over time. Observed differences among individuals and temporal changes in taste are to be explained by variations in price structure and investments in human capital. If the Becker-Stigler position has empirical consequences -- and this is a big if -- our position cannot be further away from theirs. We propose that preferences are often not only variable, vague and labile, they are downright incoherent.

REFERENCES

- Arrow, K. J. (1982). Risk perception in psychology and economics. *Economic Inquiry*, 20, 1-9.
- Coombs, C. H., Bezeminder, T. C. G., & Goode, F. M. (1967). Testing expectation theories of decision making without measuring utility and subjective probability. *Journal of Mathematical Psychology*, 4, 72-103.
- Fischer, G. W., Damodaran, N., Laskey, K. B., & Lincoln, D. (1987). Preferences for proxy attributes. *Management Science*, 33, 198-214.
- Fishburn, P. C. (1984). SSB utility theory: An economic perspective. *Mathematical Social Sciences*, 8, 63-94.
- Fishburn, P. C. (1985). Nontransitive preference theory and the preference reversal phenomenon. *Rivista Internazionale di Scienze Economiche e Commerciali*, 32, 39-50.
- Fitts, P. M., & Seeger, C. M. (1953). S-R compatibility: Spatial characteristics of stimulus and response codes. *Journal of Experimental Psychology*, 46, 199-210.
- Goldstein, W. M., & Einhorn, H. J. (1987). Expression theory and the preference reversal phenomena. *Psychological Review*, 94, 236-254.
- Grether, D. M., & Plott, C. R. (1979). Economic theory of choice and the preference reversal phenomenon. *American Economic Review*, 69, 623-638.
- Griffin, D., Slovic, P., & Tversky, A. (1987). *Compatibility effects in judgment and choice*. Unpublished manuscript, Stanford University, Stanford, CA.
- Hershey, J., & Schoemaker, P. J. (1985). Probability vs. certainty equivalence methods in utility measurement: Are they equivalent? *Management Science*, 31, 1213-1231.
- Kahneman, D., and Tversky, A. (1984). Choices, values and frames. *American Psychologist*, 39, 341-350.
- Krantz, D.H., Luce, R.D., Suppes, P., & Tversky, A. (1971). *Foundations of Measurement (Vol.1)*. New York: Academic Press.
- Lichtenstein, S., & Slovic, P. (1971). Reversals of preference between bids and choices in gambling decisions. *Journal of Experimental Psychology*, 89, 46-55.

- Lichtenstein, S., & Slovic, P. (1973). Response-induced reversals of preference in gambling: An extended replication in Las Vegas. *Journal of Experimental Psychology*, 101, 16-20.
- Loomes, G., & Sugden, R. (1982). Regret theory: An alternative theory of rational choice under uncertainty. *Economic Journal*, 92, 805-824.
- Loomes, G., & Sugden, R. (1983). A rationale for preference reversal. *American Economic Review*, 73, 428-432.
- Payne, J. W. (1982). Contingent decision behavior. *Psychological Bulletin*, 92, 382-401.
- Schkade, D. A., & Johnson, E. J. (1987). *Cognitive processes in preference reversals*. Working paper, Department of Management, University of Texas.
- Slovic, P. (1975). Choice between equally valued alternatives. *Journal of Experimental Psychology: Human Perception and Performance*, 1, No. 3, 280-287.
- Slovic, P., & Lichtenstein, S. (1968). The relative importance of probabilities and payoffs in risk-taking. *Journal of Experimental Psychology Monograph Supplement*, 78(3), part 2 (b).
- Slovic, P., & Lichtenstein, S. (1971). Comparison of Bayesian and regression approaches to the study of information processing in judgment. *Organizational Behavioral and Human Performance*, 6, 649-744.
- Slovic, P., & Lichtenstein, S. (1983). Preference reversals: A broader perspective. *American Economic Review*, 73, 596-605.
- Slovic, P., Lichtenstein, S., & Fischhoff, B. (in press). Decision making. In R. C. Atkinson, R. J. Herrnstein, G. Lindzey & R. D. Luce (Eds.), *Stevens' Handbook of Experimental Psychology*, second edition. New York: Wiley.
- Stigler, G. J., & Becker, G. S. (1977). De gustibus non est disputandum. *The American Economic Review*, 67, No. 2, 76-90.
- Tversky, A. (1977). Features of similarity. *Psychological Review*, 84, 327-352.
- Tversky, A., & Gati, I. (1978). Studies of similarity. In E. Rosch & B. Lloyd (Eds.), *Cognition and categorization*, Hillsdale, N.J.: Erlbaum.
- Tversky, A., & Gati, I. (1982). Similarity, separability, and the triangle inequality. *Psychological Review*, 89, 123-154.
- Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases.

Science, 185, 1124-1131.

Tversky, A., & Kahneman, D. (1986). Rational choice and the framing of decisions. *The Journal of Business*, 59 (4), Pt. 2, 251-278.

Tversky, A., & Sattath, S. (1979). Preference trees. *Psychological Review*, 86, 542-573.

Tversky, A., Slovic, P., & Kahneman, D. (1987). *Components of preference reversals*. Unpublished paper. Stanford University, Stanford, CA.

Varian, H. R. (1984). *Microeconomic analysis*. New York: Norton & Co.

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Dr. Daniel Kahneman
The University of British
Department of Psychology
#154-2053 Main Mall
Vancouver, British Columbia
Canada V6T 1Y7

Dr. Stanley Deutsch
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(COHF)
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Dr. Amos Tversky
Dept. of Psychology
Stanford University
Stanford, CA 94305

Dr. Deborah Boehm-Davis
Department of Psychology
George Mason University
4400 University Drive
Fairfax, VA 22030

Dr. Amos Freedy
Perceptronic, Inc.
6271 Variel Avenue
Woodland Hills, CA 91364

Dr. James T. Todd
Brandeis University
Waltham, MA 02254

Dr. David Van Essen
California Institute of Tech.
Division of Biology
Pasadena, CA 91125

Dr. Stanley N. Roscoe
New Mexico State University
Box 5095
Las Cruces, NM 88003

Dr. James H. Howard, Jr.
Department of Psychology
Catholic University
Washington, D.C. 20064

Mr. Joseph G. Wohl
Alphatech, Inc.
3 New England Executive Park
Burlington, MA 10803

Dr. William Howell
Department of Psychology
Rice University
Houston, TX 77001

Dr. Marvin Cohen
Decision Science Consortium, Inc.
Suite 721
7700 Leesburg Pike
Falls Church, VA 22043

Dr. Christopher Wickens
Department of Psychology
University of Illinois
Urbana, IL 61801

Dr. Scott Robertson
Catholic University
Department of Psychology
Washington, D.C. 20064

Dr. Robert Wherry
Analytics, Inc.
2500 Maryland Road
Willow Grove, PA 19090

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Madison, WI 53706

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Department of Psychology
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New York University
Courant Inst. of Mathematical
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251 Mercer Street
New York, New York 10012

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Graduate School of Business
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Duke University
Durham, NC 27706

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University of Oregon
Dept. of Computer & Info Sci.
Eugene, OR 97403

Dr. Donald A. Glaser
U. of California, Berkeley
Department of Molecular Biology
Berkeley, CA 94720

Dr. Tomaso Poggio
Massachusetts Institute of Tech.
Center for Biological Information
Processing
Cambridge, MA 02139

Dr. Marvin Cohen
Decision Science Consortium, Inc.
Suite 721
7700 Leesburg Pike
Falls Church, VA 22043

Dr. Whitman Richards
Massachusetts Ins. of Tech
Department of Psychology
Cambridge, MA 02139

Dr. Leonard Adelman
PAR Technology Corp.
Building A
1220 Sunset Hills Road, Suite 310
McLean, VA 22090

Dr. Alexander Levis
Massachusetts Institute of
Technology
Lab Information & Decision Systems
Cambridge, MA 02139

Dr. David Castanon
ALPHATECH, Inc.
111 Middlesex Turnpike
Burlington, MA 01803

Dr. David Noble
Engineering Research Assoc.
8616 Westwood Center Dr.
McLean, VA 22180

Dr. Baruch Fischhoff
Perceptronics, Inc.
6271 Varrel Ave.
Woodland Hills, CA 91367

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